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Research on performance of humidity-controlling materials based on E+

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Abstract

Energy-saving building quantitative assessment is often based on three major aspects. First, the building energy consumption; second, human comfort; third, the whole life cycle cost. The application of high-quality humidity-controlling materials will optimize these three indicators. At present, active air conditioning adjustment is also mainly used to meet building internal humidity demand in China. Though it can meet the comfort requirements of architectural space, the building energy consumption is large. It is not in accordance with the sustainable development strategy. Using humidity-controlling materials is passive, green, non-pollution, zero-energy and sustainable way with great potential development space. The paper simulated a building with different envelope inner surface humidity-controlling materials from human comfort, energy consumption and economy of three aspects by energy consumption analysis software EnergyPlus. Meanwhile painting as control group is contrasted and analyzed. The results showed that humidity-controlling materials have great advantages in these three aspects. Humidity-controlling materials can regulate indoor air humidity and reduce energy consumption. Besides the whole life cycle cost can get to minimum. This article provides a theoretical basis and a technical guidance for humidity-controlling materials market promotion and building energy saving.

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Keywords: Human comfort; Energy consumption; Economic; Humidity-controlling materials.

1. Introduction

Humidity-controlling materials with moisture transferring characteristics can stabilize the indoor relative humidity (RH) within a certain range. It can rely on the moisture content difference between the air and their own to feed back to the room air humidity. Suitable indoor air humidity can improve human comfort and optimize indoor air quality and protect indoor furniture items. Humidity-controlling materials may be natural materials. They also can be

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made from renewable energy sources to be environmental economic material from the straw or other agricultural waste. Development of compound ecological materials will solve the problem of construction waste. They don't increase environmental burden by natural degradation to really achieve green non-pollution sustainable development. To add the humidity-controlling materials in the building inner surface can assist air conditioning system running, undertaking part of the wet load, reducing the air conditioning load to bear latent heat, reducing building energy consumption. Ideal humidity-controlling materials should have high debugging efficiency, high absorption capacity and cheap green characteristics.

1.1. Humidity-controlling materials category

Humidity-controlling materials apply to different scopes of application due to respective characteristics. They can be divided into chemical and physical adsorption by adsorption, organic and inorganic depending on material varieties, natural and synthetic materials according to the preparation method[1]. Humidity-controlling materials category is shown in Table 1 depending on the domestic and foreign scholars in the field.

Table 1. Humidity-controlling materials category

Classification	Ingredient	Characteristic	Application	Notes
Inorganic silicon	Amorphous silicon dioxide	Superior moisture absorption capacity and moisture absorption rate, a more severe hysteresis during the moisture absorption and desorption cycle	Ideal dry sorbent	High-cost, limited application
Inorganic mineral humidity-controlling materials	Montmorillonoid, kaolin, kieselguhr, zeolite powder, sepiolite	Symmetrical permeability, high temperature resistance, resistant to corrosion, swift water absorption and desorption speed(especially the desorption speed), non-toxic and harmless to humans and the environment	Building wall	Cheap, a wide raw materials source , long service life, popular and mature application
Inorganic salt humidity-controlling materials	Inorganic salt saturated salt solution	Large moist storage capacity, swift absorption and desorption rate, deliquescent, unstable	Porous saliferous concrete material	Easy to produce pollution, limited application, having research value
Organic polymer humidity-controlling materials	High-molecular polymer	Fast moisture absorption rate, large moisture content, diverse type, common moist desorption performance	Suit different occasions	Complicated production process, high manufacturing cost, short functional life
Natural humidity-controlling materials	Wood, bamboo charcoal, activated carbon	Different humidifying properties, Bamboo charcoal can deodorize	Add in the wall inner surface	Green & Environmental protection, no pollution
Composite biomass humidity-controlling materials	Crop wastes (straw, rice straw, wheat straw, bean straw, cotton stalks, husks, etc.)	No pollution, lightweight, energy saving	Add in the wall inner surface	Having a good prospects

1.2. The humidity-controlling mechanisms of humidity-controlling materials

The humidity-controlling mechanisms also vary because of the different types of humidity-controlling materials. For example inorganic humidity-controlling materials absorb and desorb water vapor molecules by its rich porous structure. When the partial pressure of water vapor in the air is greater than the saturated vapor pressure of water in the holes, the water vapor around the wall is adsorbed into holes of the humidity-controlling materials. Otherwise, the water vapor breaks away from holes, then releases into the surrounding air. The humidity-controlling mechanisms of polymer humidity-controlling materials is that organic molecule with polar group in the humidity-controlling materials combine with the water molecules in the air by Van der Waals and hydrogen bonding. The humidity-controlling effect of inorganic salt humidity-controlling materials is decided by the saturation vapor pressure. The lower the saturated vapor pressure is, the weaker absorption capacity is [3]. The humidity-controlling materials in the form of coating or sheet are added into the inside surface of building. Humidity-controlling materials can control the water vapor content by "highly absorb and lowly desorb", so that they can reduce indoor humidity fluctuations, then the indoor humidity is adjusted in the human comfort range. Meanwhile they greatly reduce the latent heat load which air-conditioning system need to remove to save energy and reduce exhaust. Fig. 1. is a moisture absorption and desorption isotherm curve of ideal humidity-controlling materials. When the indoor RH is inferior to Φ1, humidity-controlling materials quickly desorb moisture, then water content in the materials decreases, so that indoor RH increases. When the indoor RH is higher than Φ2, humidity-controlling materials quickly absorb moisture, the water content in the materials increases, so that indoor RH declines. When the water content of the materials is controlled between U1 and U2, indoor RH is maintained within Φ1 to Φ2. If regulative RH is closer to 40%-60%, meanwhile absorption and desorption curve in this range is steeper, then the humidity-controlling materials will meet the indoor environment. And the response will be better[4].

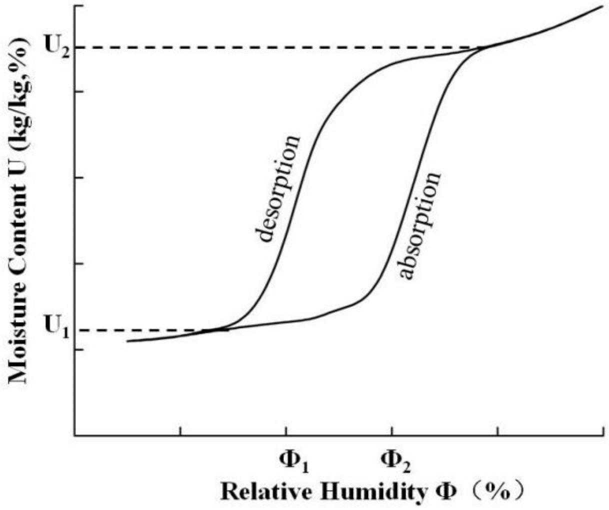

Fig. 1.Isothermal sorption curve of humidity-controlling material

2. Simulation Properties

The building is a simple office house. It located in Shenyang. The building lays north to south with 3.6m storey height. Construction area is 30m^2. Window, length 2m, height 1.2m. Door, width 1.2m, height 2m. Wall, high 3.6m. Lighting level is 11W/m2. The architectural model is shown in Fig. 2. It is modeled by SketchUp and OpenStudio. Equipment level is 13W/m2. The natural ventilation rate is 0.0083 m^3/s·people. The office is controlled by ideal air-condition. The maximum heating supply air temperature is 50℃. The minimum cooling supply air temperature is 13℃. The maximum heating supply air humidity ratio is 0.018(kg · water)/(kg · dry air). The minimum cooling supply air humidity ratio is 0.01(kg · water)/(kg · dry air). The office temperature is controlled by between 20℃ to 25℃.

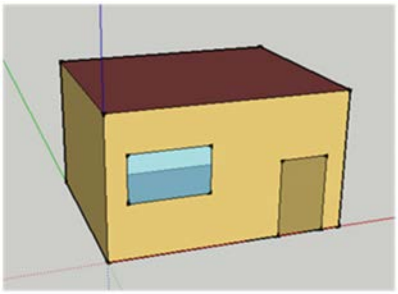

Fig. 2. Architectural model

In order to analyze different humidity-controlling materials performance, this paper adds five different type humidity-controlling materials into building inside wall. They include gypsum board, mortar, spruce, wood fiber board, light clay mortar and painting as control group. Physical property parameter of materials is referred from IDFeditor dataset in EnergyPlus, material information in Champs and ASHRAE RP-1018 databases [4]. External wall and roof construction is shown in Fig. 3. and Fig. 4. Wherein Light clay mortar ingredients have a little of clay with comparing with mortar group. Wood fiber board adds into some good humidity control performance of plant fiber comparing with spruce group.

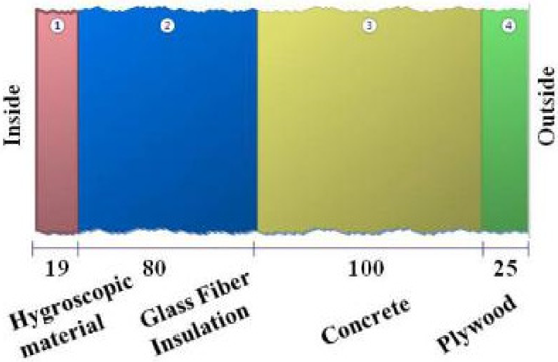

Fig. 3. Wall Construction

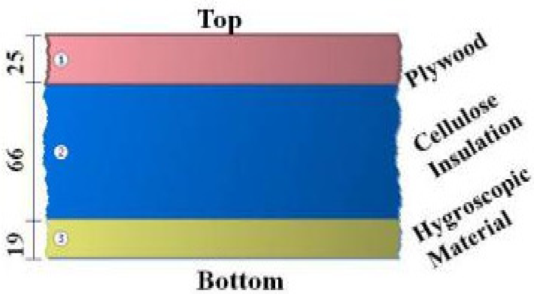

Fig. 4. Roof Construction

3. Results and Discussion

3.1. Human comfort analysis

With the development of society, living standards gradually improves. People comfort requirements in the building get higher and higher. The high-quality of air, comfortable temperature and humidity environment, reasonable air distribution can make body in a normal physiological range. It can expend minimal energy consumption to maximize function to reduce fatigue and improve work efficiency.

In this section, indoor RH is simulated when envelope inside surfaces are added several different humidity-controlling materials. An average indoor RH point is outputted every hour. Air conditioner is used whether to control humidity. Household air conditioner only control temperature but no air humidity. It belongs a decentralized air conditioning. Group Fig. 5. is shown indoor RH curves using different humidity-controlling materials under this type household air conditioner. Central air conditioning is controlled by temperature and humidity joint operation, including centralization and semi-centralization. Group Fig. 6. is shown indoor RH curves in this form of air-conditioned. It is generally considered that 40%-60% RH meet human health and comfort standards. It is said that 40%-65%RH in summer and 30%-60%RH in winter are ruled in a comfortable air-conditioned room in "heating, ventilation and air conditioning design specifications". Nice humidity-controlling materials should maintain indoor RH in this range in more time, minimizing indoor humidity fluctuations.

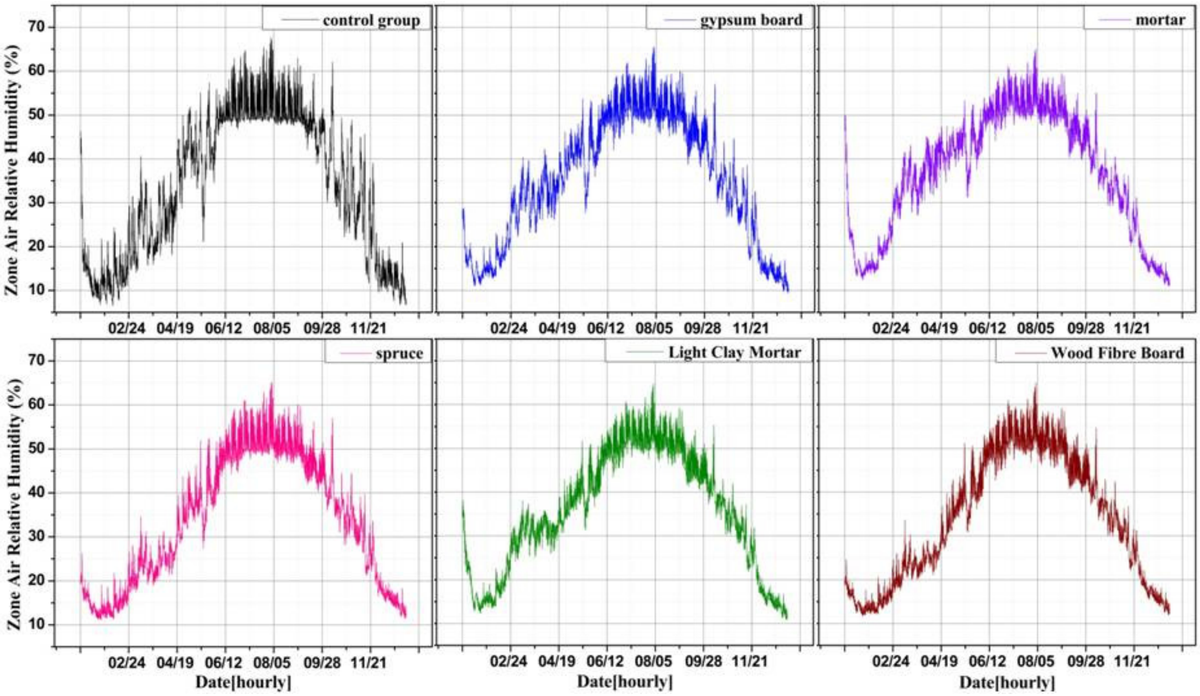

Fig. 5. Indoor RH under household air conditioner controlling

Group Fig. 5. shows indoor air humidity fluctuations throughout the year is the largest in the control group. The adjacent fluctuation range is about 20% RH. It is be the most uncomfortable. Indoor humidity fluctuate have greatly improved in other five groups adding humidity-controlling materials. The indoor humidity fluctuations in the gypsum group is larger than one in the mortar group. Indoor RH fluctuations in the Light clay mortar group is slightly less than the mortar group. Similarly, Indoor RH fluctuations in the wood fiber board group is slightly less than the spruce group. It is illustrated that high-performance humidity-controlling materials can control indoor RH steadily. The time of indoor 40%-60% RH in the mortar group and light clay mortar group is longer than one in the spruce group and wood fiber board group. The formers have better performance. Indoor humidity differences are large in the beginning of January because of different initial water content in the materials. Then the indoor RH is close to accordance after 20 days. Indoor air is dry due to heating in winter. We can find that the indoor RH reaches 12% in Jan and Dec, so residents need to regulate indoor humidity by means of humidifier.

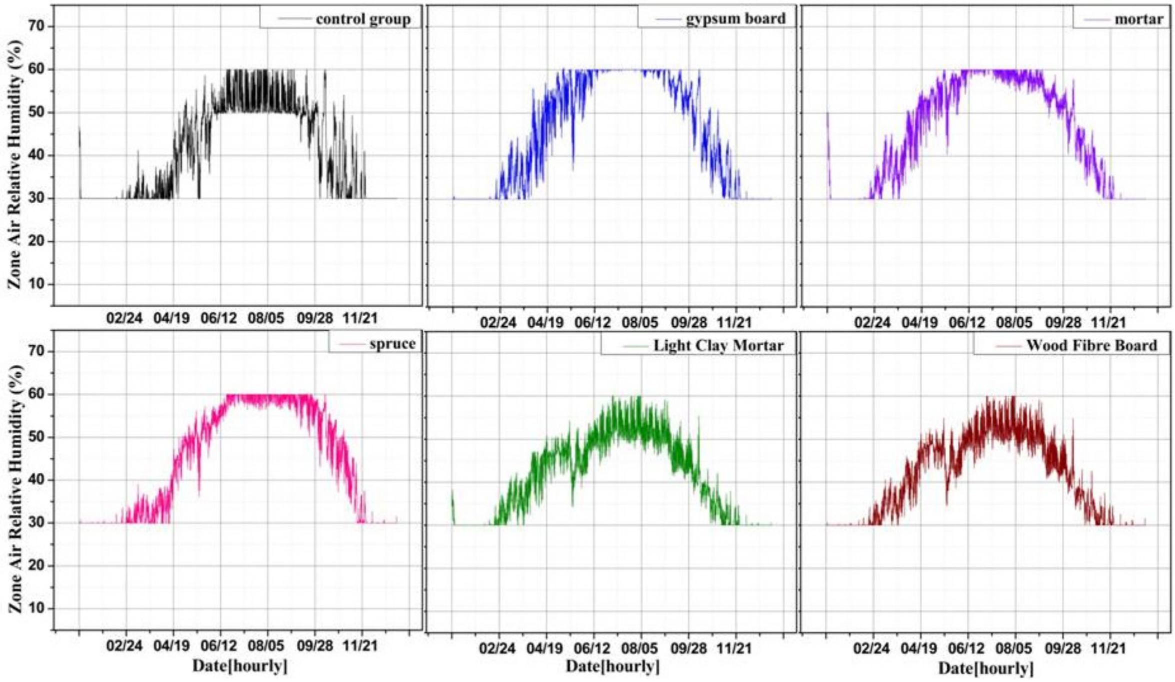

Fig. 6. Indoor RH under central air conditioning controlling

Group Fig. 6. is shown that indoor air RH is controlled between 30% and 60%. It is illustrated that humidity-controlling material is able to regulate air humidity, but it must combine air-condition with humidity-controlling function in order to pursuit a comfortable environment. As group Fig. 5., humidity fluctuation is the largest in the gypsum board group. The indoor RH is close to 60% during June to September in the gypsum board group, mortar group and spruce group as these three types materials already get to saturation in these indoor RH range. So excess water vapor in the air is handled by air conditioner. Although indoor air humidity fluctuation in the light clay mortar group and wood fiber board group is larger than other humidity-controlling materials during June to September. But the time of RH closing to 50% is more. So these two groups have better performance than others. The stronger performance is, the better control is.

3.2. Zone load and annual energy consumption analysis

Currently, environmental problems including air pollution and energy shortage have caused people's attention. Building energy efficiency as an important means of energy saving has large energy-saving potential. Using energy-saving building materials can reduce energy consumption. If humidity-controlling materials is promoted, we need to assess all aspects of the energy-saving effects. Fig. 7.,Fig. 8. and Fig. 9. are shown zone load, annual cooling and heating energy and total annual energy consumption.

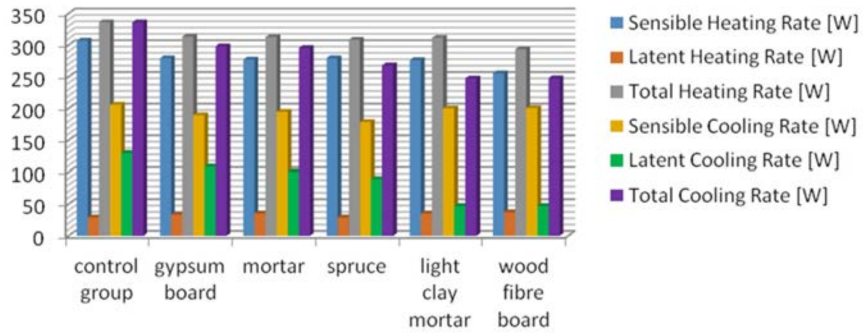

Fig. 7. Zone Ideal Loads

According to above load energy consumption pictures, we can see as several humidity-controlling materials group optimize humidity-performance, sensible heating energy and latent cooling energy hold downward trend, while latent heating energy and sensible cooling energy do not change significantly. Overall, total heating energy and total cooling energy has reduced as humidity-controlling ingredients increasing. We can conclude that humidity-controlling materials have obvious advantage in the total energy. They are more conducive to building energy efficiency.

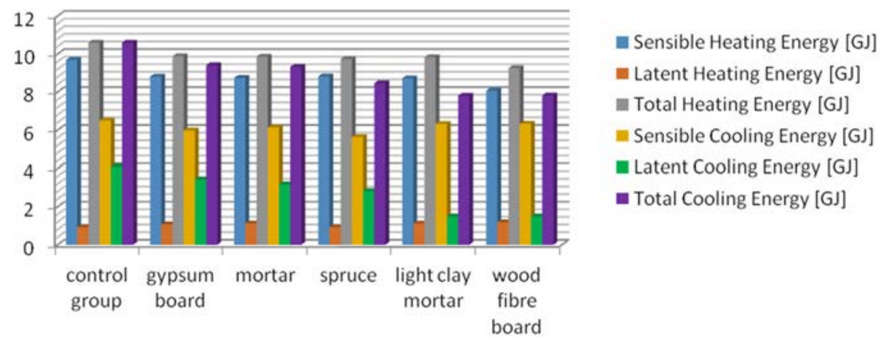

Fig. 8. Energy Uses

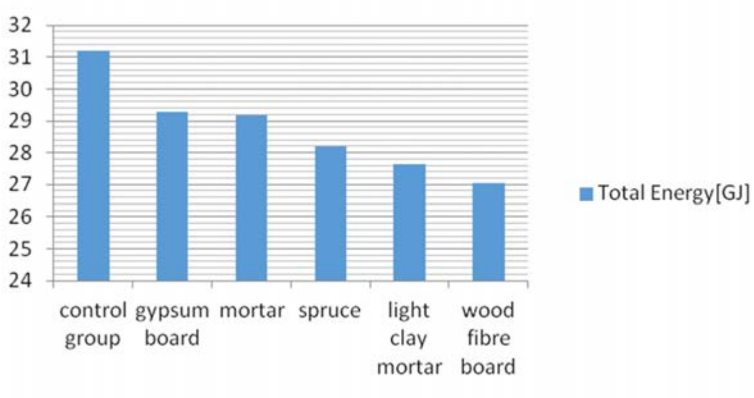

Fig. 9. Total Energy

3.3. Economic analysis

In response to prevent global warming, China promote green building strategies. Establishing a resource-saving and environment-friendly society to achieve sustainable development for architecture [5]. However, facing the cost of green materials are often relatively expensive. This attendant problem also hinder the development of green buildings. Now researches on green building stay in the environmental dimension, ignoring the expense of green building economic analysis, which cause a green building rating system out of touch with the economic benefits [6]. So the building life-cycle cost analysis is particularly important.

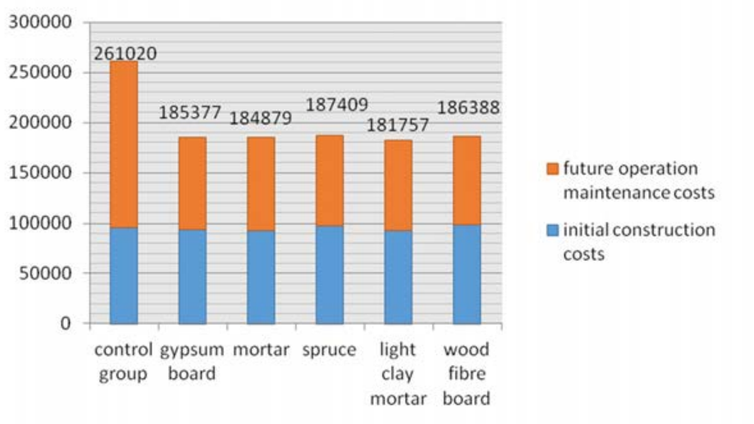

Fig. 10. Life Cycle Cost

LCC (life cycle cost) refers to the building cost from material acquisition, material transport, building design, construction, use operation, maintenance and dismantling recovery during the entire cycle. Life cycle cost of the building is continuous generate cost for a long period and the value of money will change with time. In order to correctly evaluate the economic effects, we need to take money at different points into money at the same time. Compare the cost base on same foundation [7]. In this study, commonly used period in residential construction is generally 50 years as a research cycle, considering the time value of money. Building cost using several materials are analyzed by converting life cycle cost to the beginning time point. By comparing the economic costs, elect humidity-controlling material with the best comprehensive benefit. Fig. 10. is shown the life cycle costs.

According to the Fig. 10., we find construction cost using humidity-controlling materials has little difference with the control group. In general, the wood material price is slightly higher than gypsum and mortar. Operating cost accord with building energy consumption. Humidity-controlling materials have obvious advantages to pursuit the maximum comprehensive benefits. Life cycle cost saving is up to 40%. Recyclable materials and sustainable materials are the most prominent in the humidity-controlling materials.

4. Conclusion

This article introduces the basic classification and mechanism of the humidity-controlling materials. Then the building using humidity-controlling materials is studied from three aspects which include human comfort, building energy consumption and building life cycle cost by using energy consumption analysis software EnergyPlus. The results showed the humidity-controlling materials can control indoor air humidity change, improving human comfort, but they need to cooperate with center air condition because of the limited the humidity performance in order to get comfortable environment. In energy efficiency terms, energy-saving effect of the humidity-controlling materials is remarkable. The better the performance of the humidity-controlling material is, the smaller building energy consumption is. In economic terms, using humidity-controlling materials have a great advantage against painting stucco building on life cycle cost. Life-cycle cost savings is up to 40%. The construction cost of different humidity-controlling materials have little difference. Overall, the humidity-controlling material has great potential to promote and apply.

5. Outlook

While domestic and foreign scholars have been working on heat and moisture transferring performance on humidity-controlling materials. But physical properties are inadequate due to numerous variety of humidity-controlling materials. Therefore, data collected in this research process has also faced a lot of resistance. If complete performance parameters database are created, study on humidity-controlling materials will greatly be promoted.

Existing experimental study tested isothermal moisture and water vapor permeability curves and other physical parameters, lacking of data of materials applied to the real space. The measured data includes indoor temperature and humidity, radiation temperature and humidity of wall inside surface and PMV, PPD statistics.

The absorption and desorption process is often accompanied by heat transferring, so indoor temperature also has been influenced. Researchers tend to focus on relationship between indoor RH and humidity-controlling materials, ignoring the impact on the indoor temperature. Researchers assess the living environment comfort objectively, only need to taking into account various parameters affected by humidity-controlling materials to select the superior humidity-controlling materials.

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